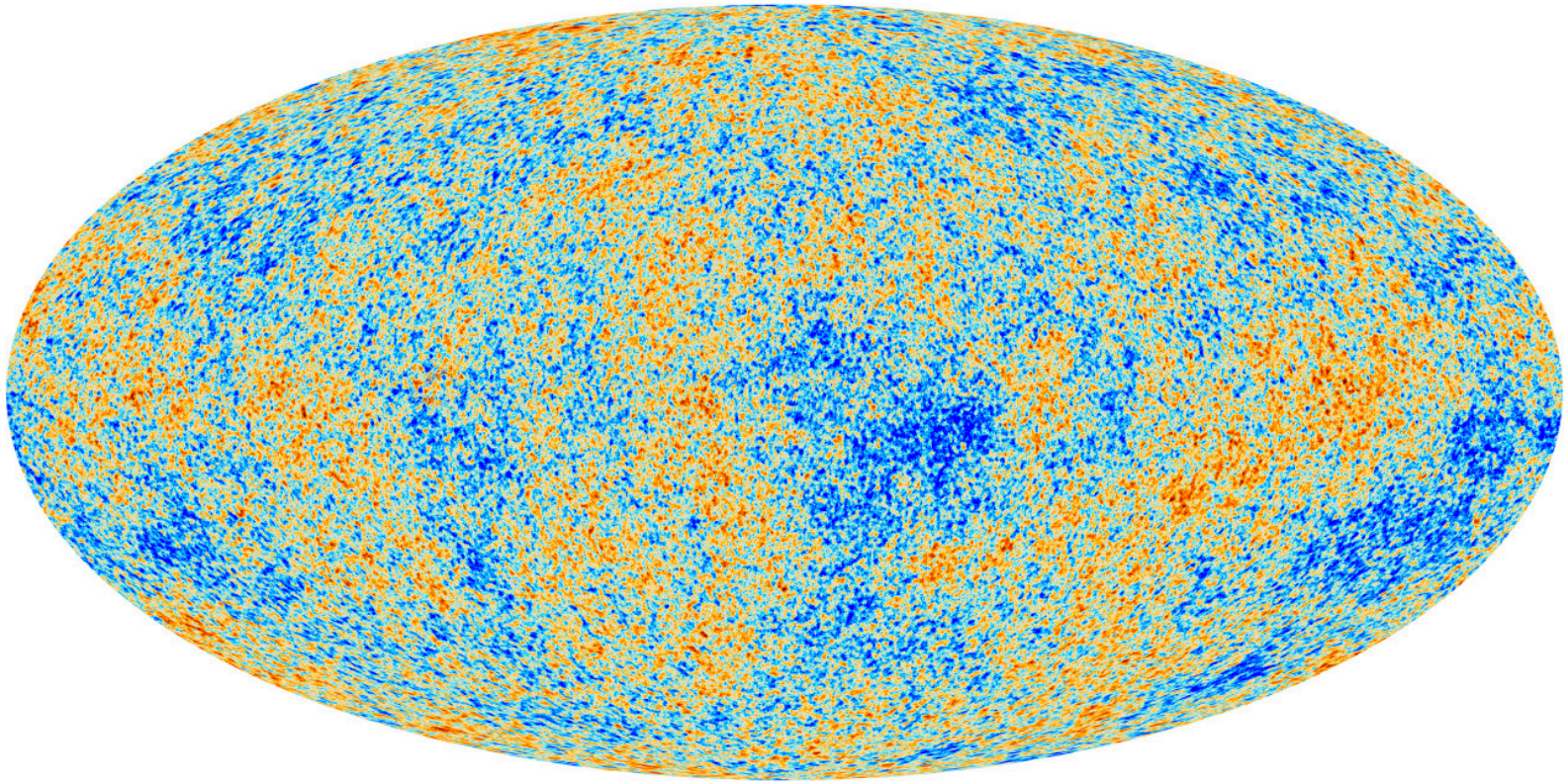
Pattern of perturbations from a Coherent Inflationary Horizon

Craig Hogan
U. Chicago and Fermilab
https://arxiv.org/abs/1811.03283
https://arxiv.org/abs/1908.07033

Cosmic structure is a relic of quantum fluctuations during inflation

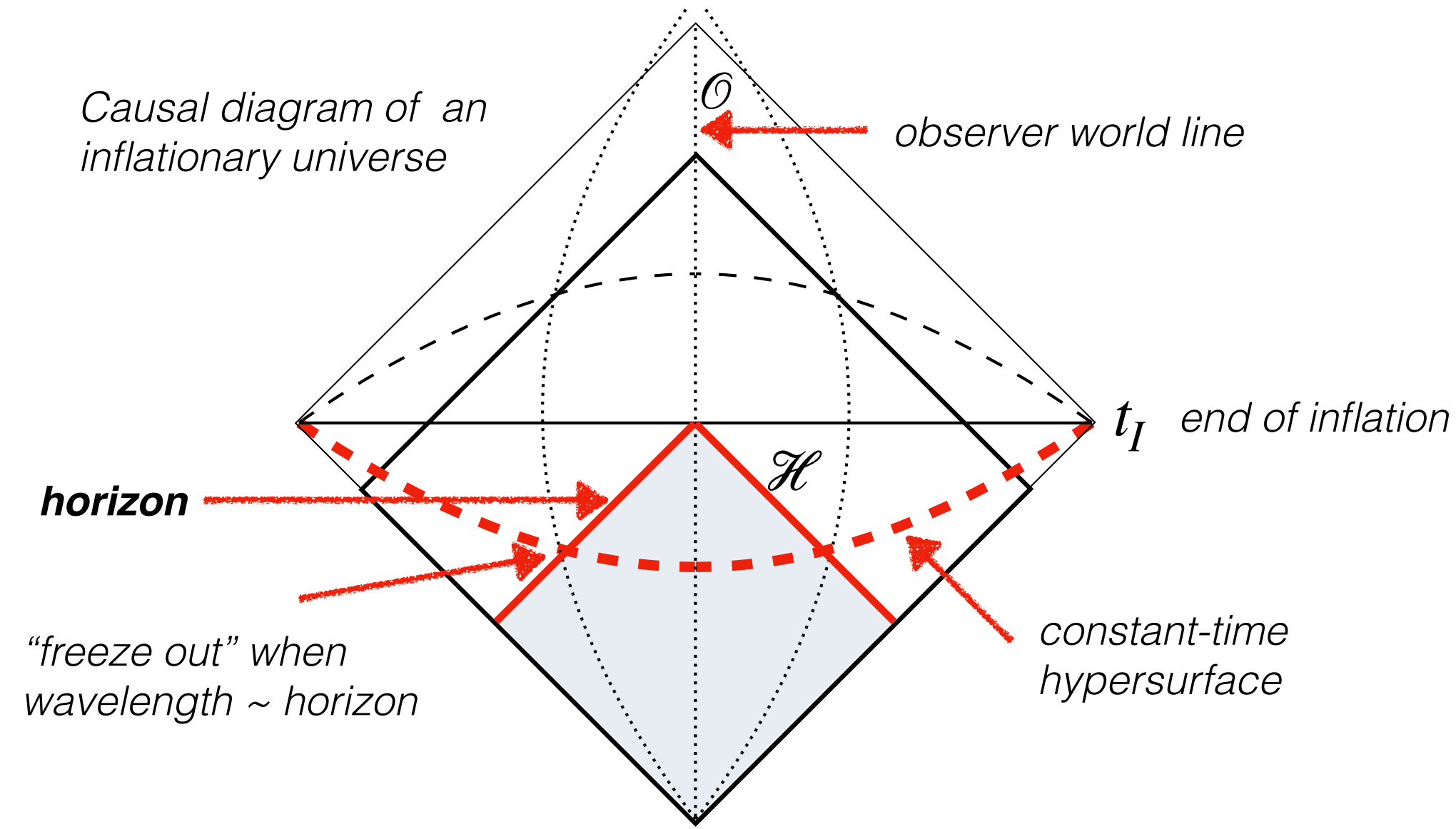


The specific pattern on large angular scales is an intact image of a primordial quantum state

Its correlations contain information about the quantum state

Standard quantum inflation: perturbations freeze out from infinite, independent ***plane wave mode amplitudes of a quantum field vacuum*** *on constant time hypersurfaces*

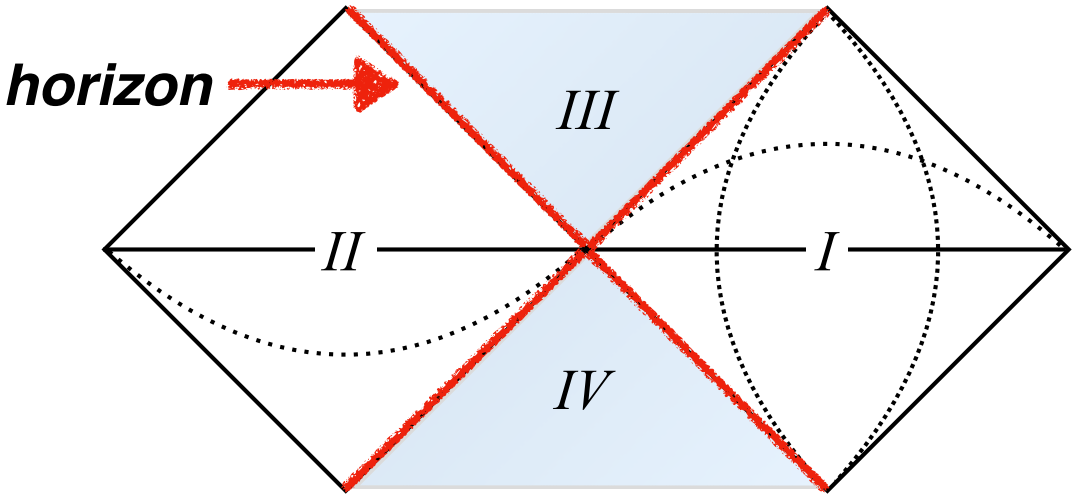
This quantum model might be wrong



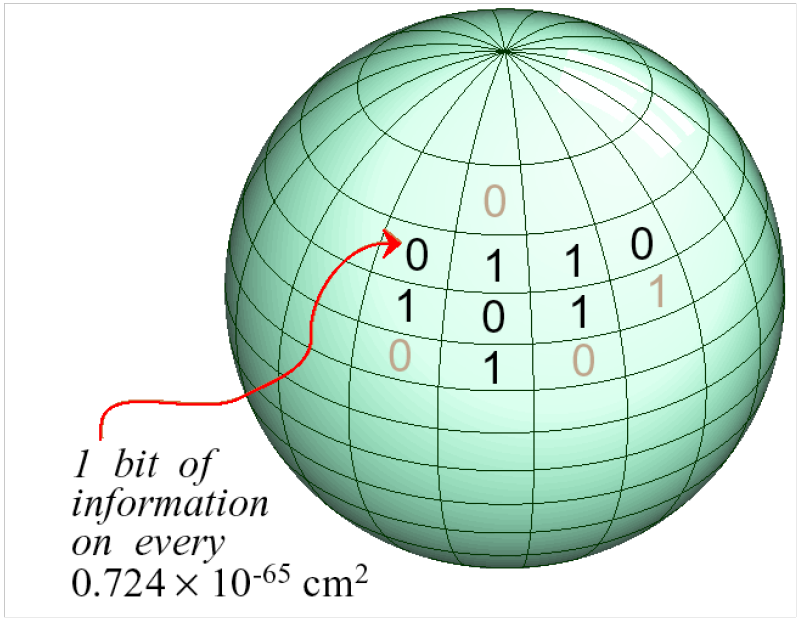
Black hole information theory suggests that quantum geometry is radically different from quantum fields

Geometrical information is nonlocal and holographic

Black hole horizons are nonlocal, coherent quantum objects



Penrose diagram of an eternal black hole, adapted from 1605.05119



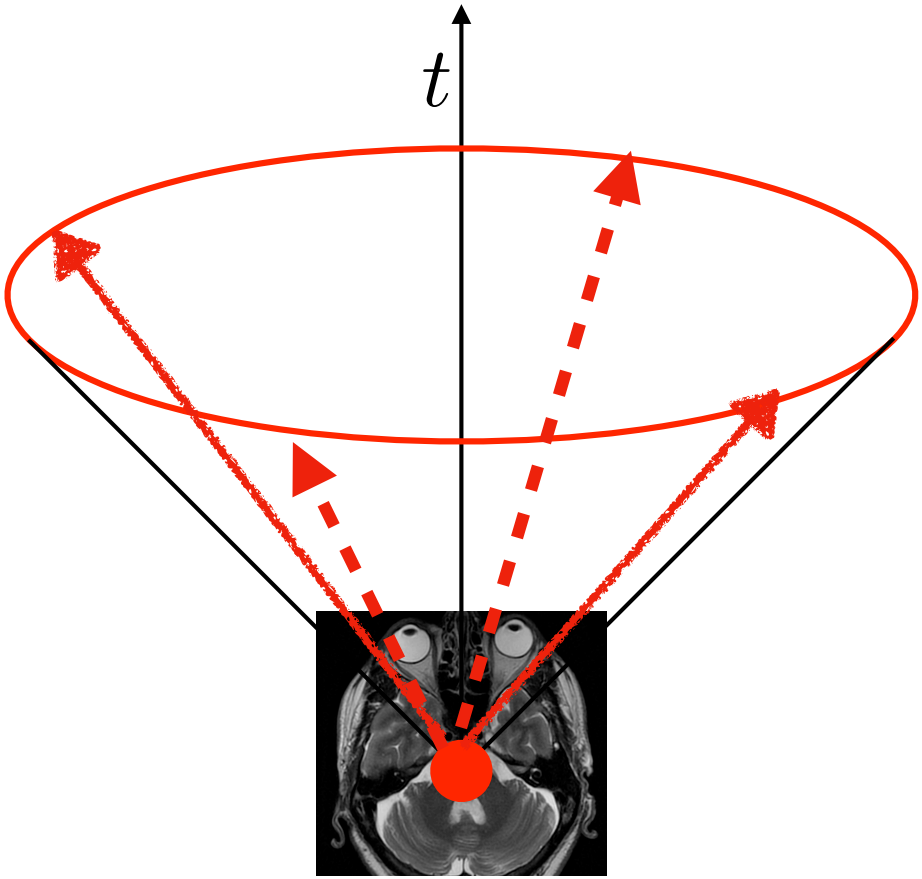
"If it is true that vacuum fluctuations include virtual black holes, then the structure of space-time is radically different from what is usually thought."

—- G. 't Hooft, Found Phys (2018) 48:1134

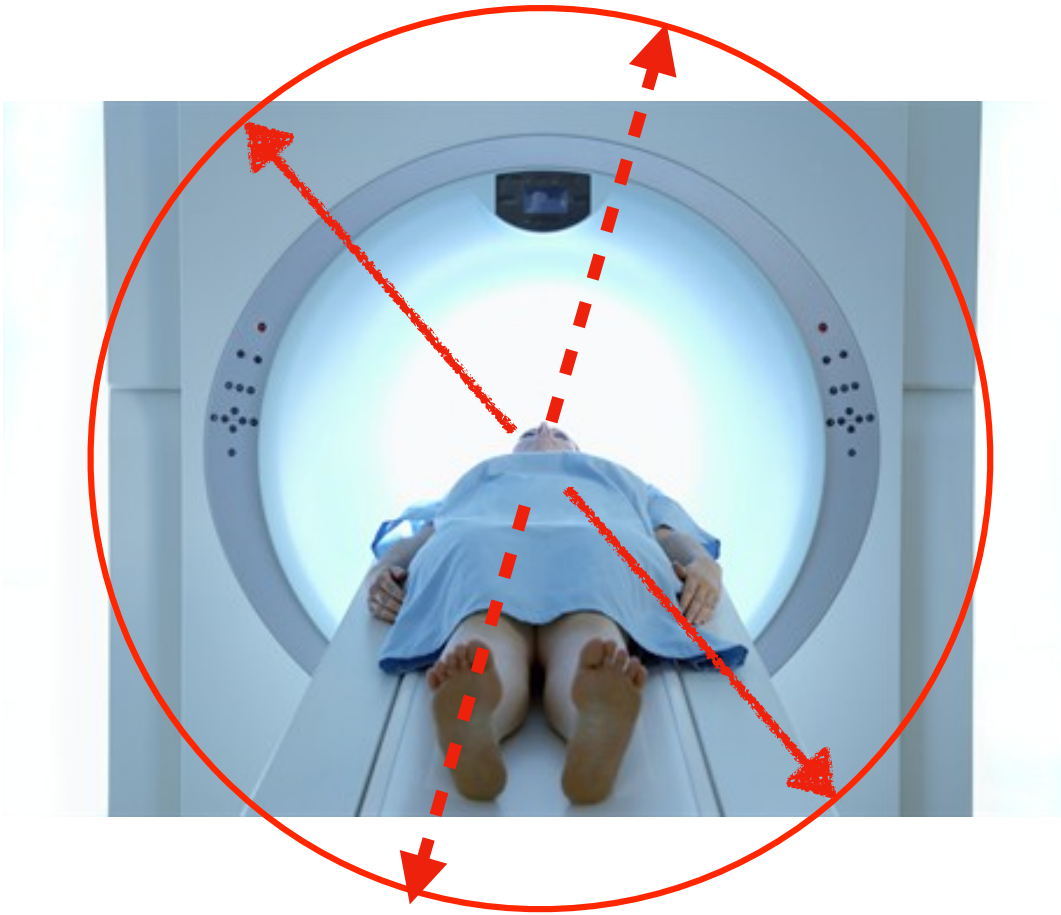
Standard decoherence on light cones: nonlocal but causal

Quantum state of "two" photons lives on a light cone
Spooky coherence extends indefinitely on a light cone
Quantum geometry should have the same structure

World line of PET scan sample



PET detector= causal surface



If inflation is like a black hole,

The inflationary horizon is a coherent quantum object

Perturbations = quantum noise in the emergence of locality

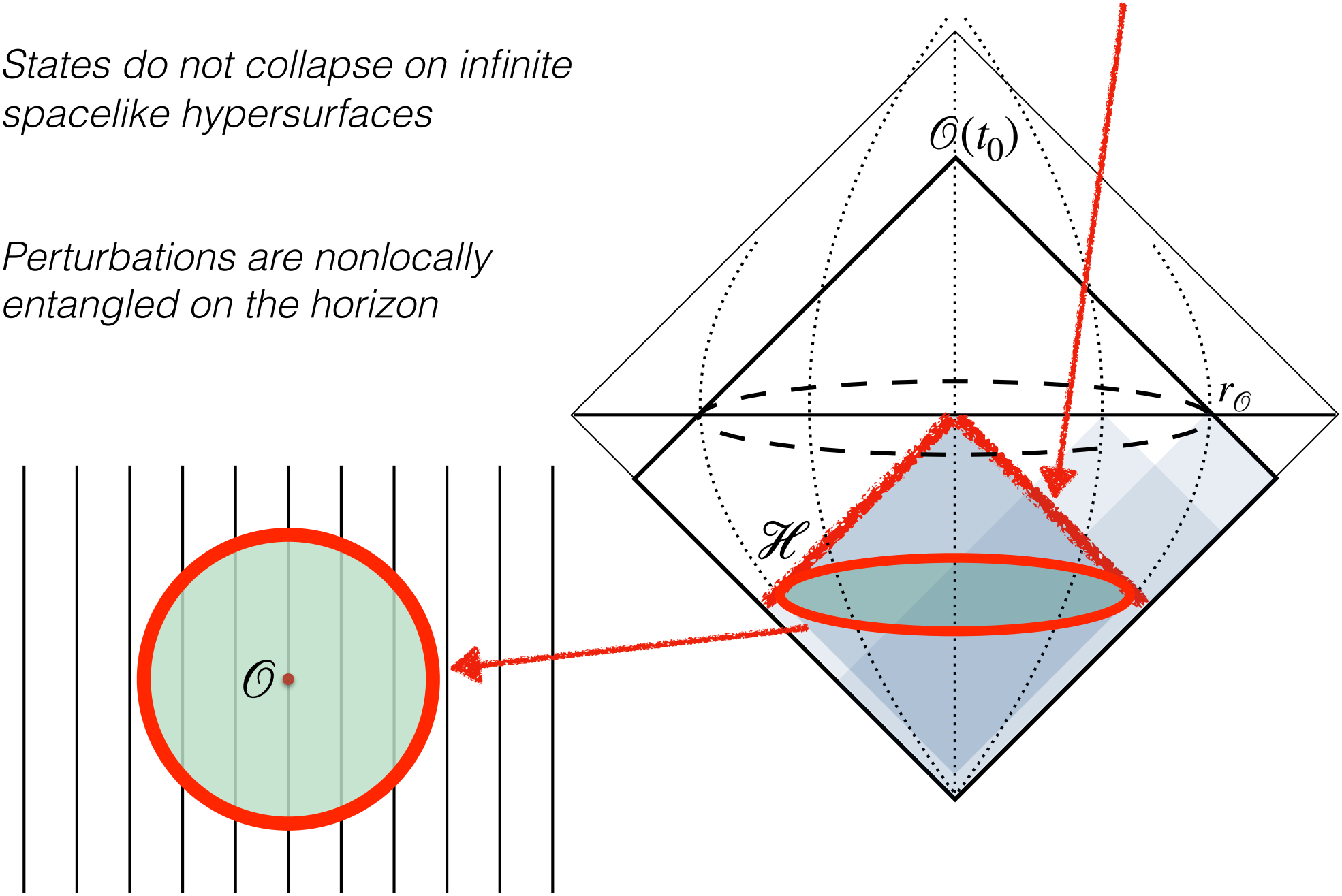
They have nonlocal holographic correlations everywhere on the horizon

Decoherence happens on causal diamonds*, not field modes*

In holographic inflation, perturbations freeze out ***on the horizon*** $\mathscr{H}$

States do not collapse on infinite spacelike hypersurfaces

Perturbations are nonlocally entangled on the horizon



potential is indeterminate inside the horizon, classical outside

Power spectrum is standard

Post-inflation evolution of each mode is standard

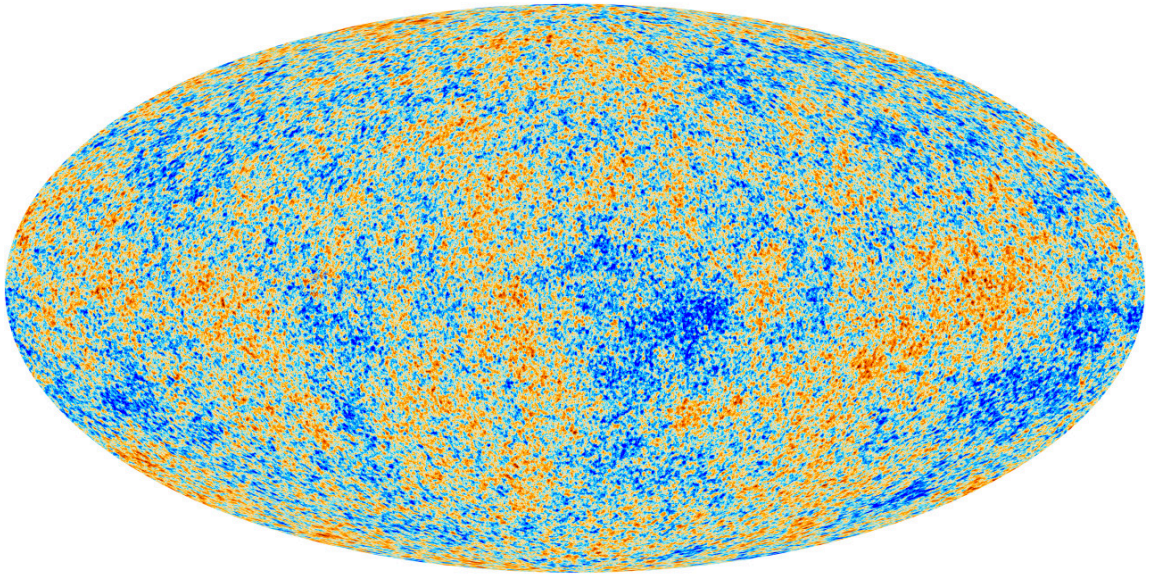
Everything that only depends on the power spectrum stays the same in holographic inflation

But now quantum modes are globally entangled

Primordial phases of relic modes in different directions are globally correlated

Does the real universe behave in this strange way?

Maybe a holographic pattern is staring us in the face!



CMB temperature ~ nearly-intact primordial pattern

A holographic information deficit requires new symmetries of angular structure at large angular separation

Perturbations are constrained by ***causal symmetries***

Example: incoming quantum phase information determines polar values of potential along any given axis on the horizon

It only reaches the equatorial plane at the end of inflation, so it cannot affect the potential for points in that plane

Mean curvature on any great circle is uncorrelated with the sum of its polar values

Predicted symmetry: *angular correlation function*

$$C_T(\Theta) \equiv \langle \delta T_a \delta T_b \rangle_{\angle ab=\Theta}$$

vanishes at 90 degrees

$$C_T(90^\circ) = 0$$

Another example: antipodal antisymmetry like black holes leads to

$$C_T(180^\circ) < 0$$

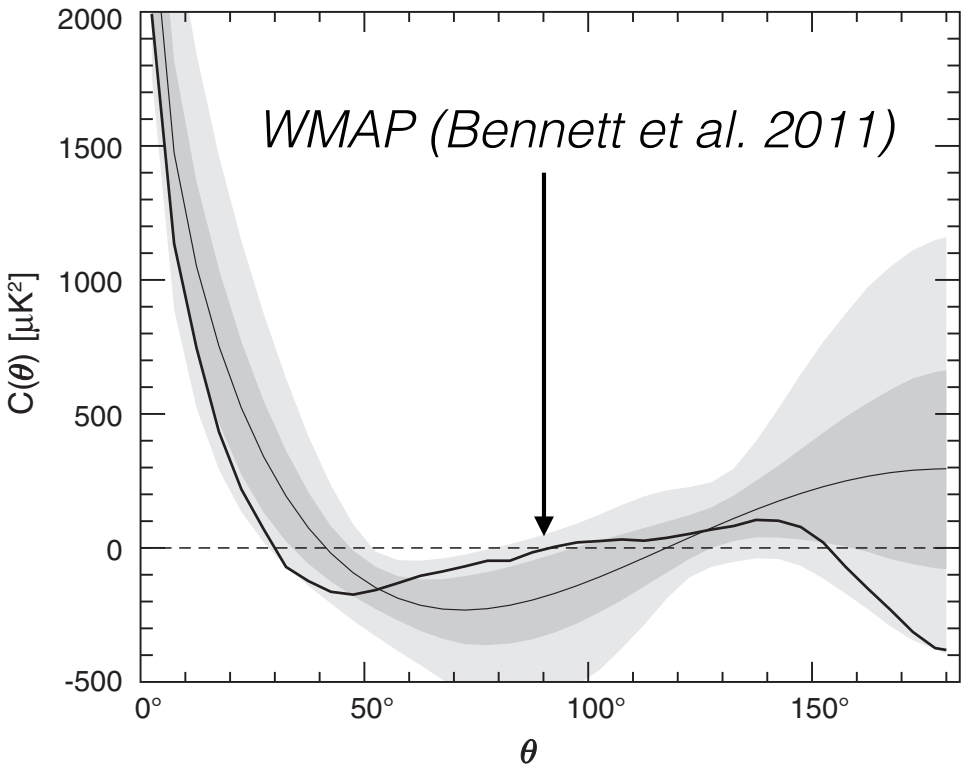
$C_T(90°) = 0$

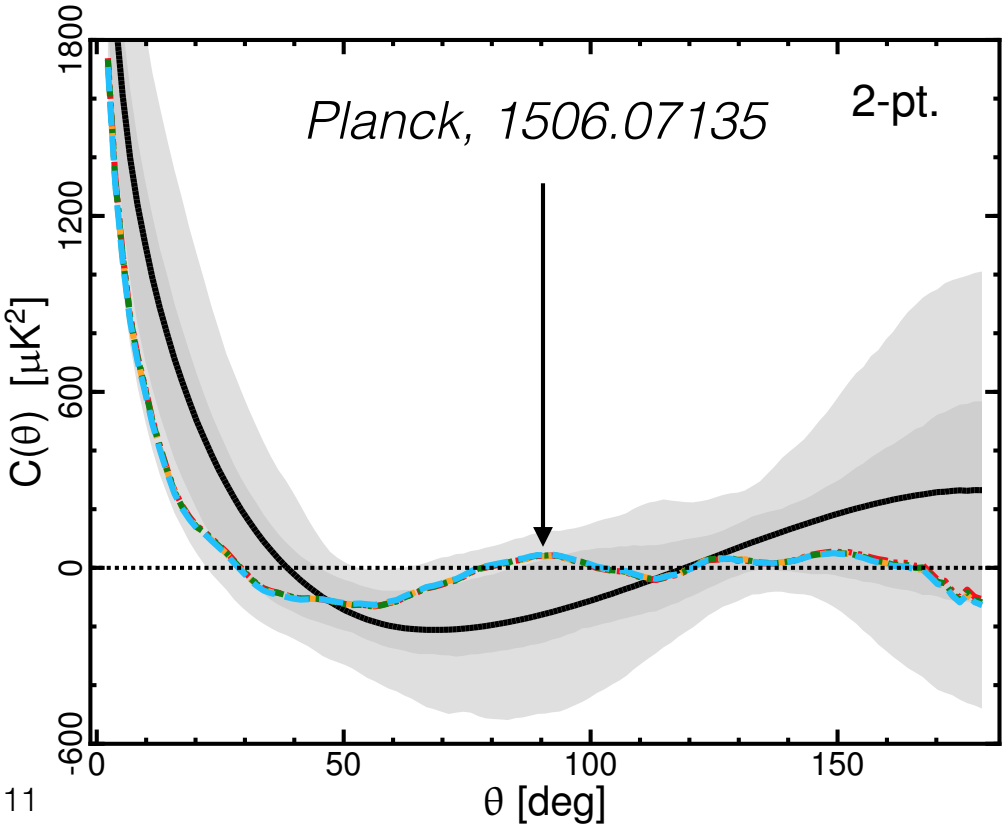
Predicted independent of the unmeasured dipole

Is it true for the actual sky?

WMAP and Planck do not agree in detail

Test requires new attention to foreground masking



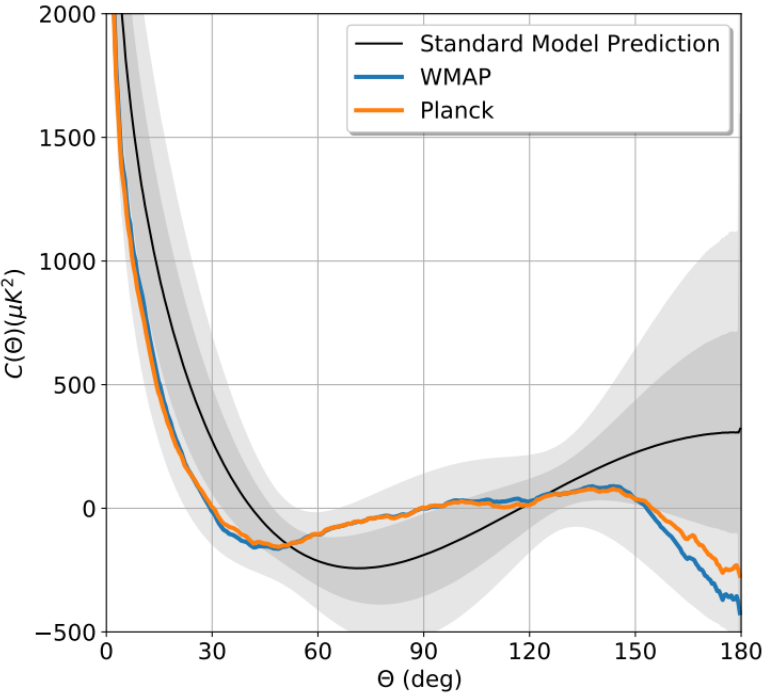


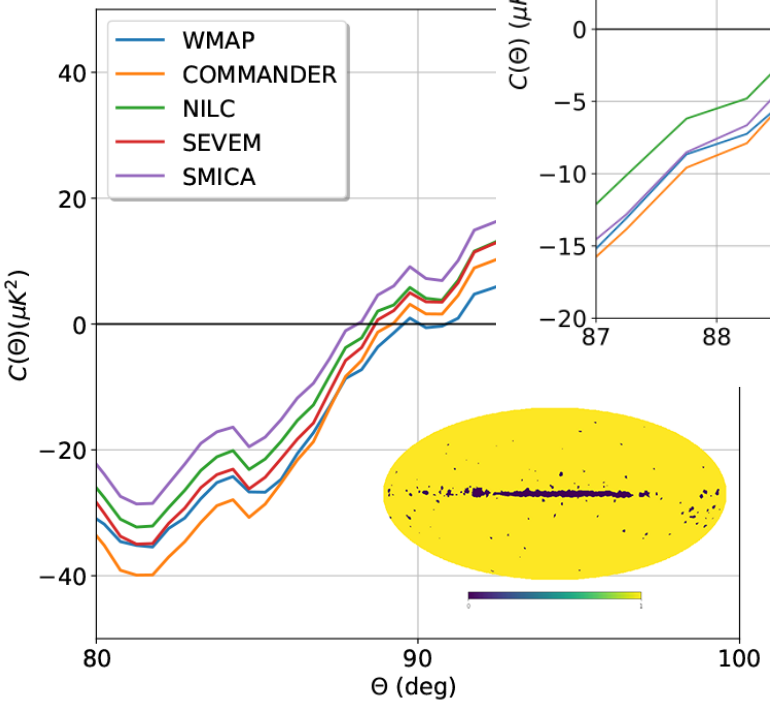
Poster session (Hagimoto, Lewin, Hogan, Meyer):
"Symmetries of CMB Correlation at Large Angular Separation"

New estimates of WMAP and Planck temperature anisotropy without masking bias agree with the predicted symmetry,

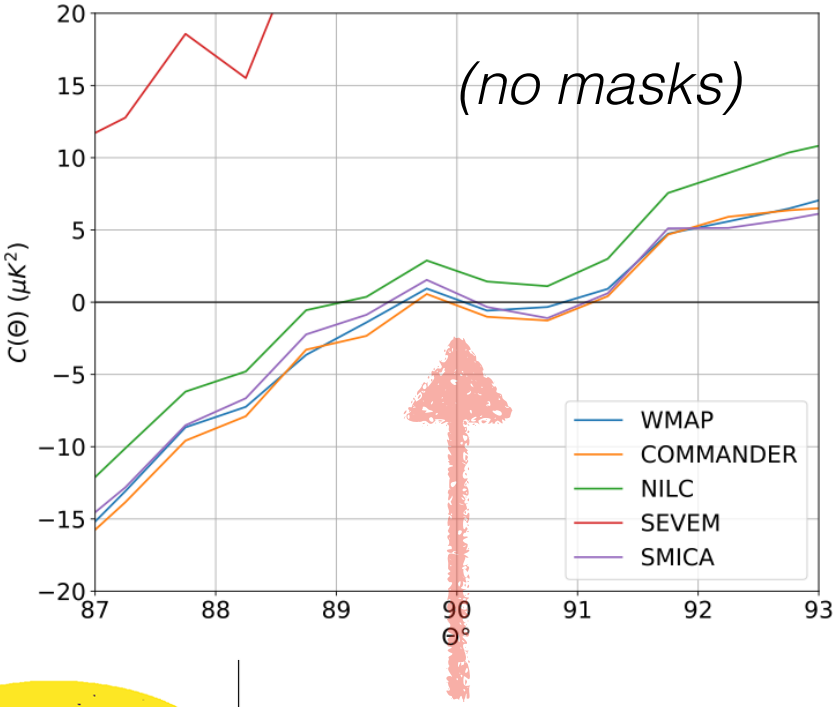
$$C(90°) = 0,$$

to within about $\pm 1 \mu \mathrm{K}^2$





(small masks)



miracle or symmetry?

Summary

The standard quantum model of inflation might be wrong

Famous “information paradoxes” in black hole theory can be resolved if horizons are coherent quantum objects

Similar holographic coherence on the inflationary horizon agrees with standard cosmological measurements

It leads to perturbations with new, unique symmetries that can be (but have not yet been) rigorously examined in CMB anisotropy and large scale galaxy surveys

It might be possible to measure analogous effects in the laboratory (see talk by Kwon in the other session)